DEPARTMENT OF MECHANICAL ENGINEERING

M.TECH COURSE STRUCTURE & SYLLABUS

THERMAL ENGINEERING PROGRAMME

(Applicable for batches admitted from 2025-2026)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA

DEPARTMENT OF MECHANICAL ENGINEERING
R25 M.TECH (THERMAL ENGINEERING) SYLLABUS

I -SEMESTER

<table>
<tr><th>S.No</th><th>Course Code</th><th colspan="2">Course Title</th><th>L</th><th>T</th><th>P</th><th>C</th></tr>
<tr><td>1</td><td>TE 101(Core-1)</td><td colspan="2">Advanced Heat Transfer</td><td>3</td><td>1</td><td>0</td><td>4</td></tr>
<tr><td>2</td><td>TE102 (Core-2)</td><td colspan="2">Advanced Fluid Mechanics</td><td>3</td><td>1</td><td>0</td><td>4</td></tr>
<tr><td></td><td>TE103 (Core-3)</td><td colspan="2">AI&ML for Mechanical Engineering</td><td>3</td><td>1</td><td>0</td><td>4</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">Program Elective – I
TE 104</td><td>TE 1041</td><td>Advanced Power Plant Engineering</td><td rowspan="4">3</td><td rowspan="4">0</td><td rowspan="4">0</td><td rowspan="4">3</td></tr>
<tr><td>TE 1042</td><td>Cryogenic Engineering</td></tr>
<tr><td>TE 1043</td><td>Turbo Machines</td></tr>
<tr><td>TE 1044</td><td>Advanced Thermodynamics & Combustion</td></tr>
<tr><td rowspan="4">4</td><td rowspan="4">Program Elective – II
TE 105</td><td>TE 1051</td><td>Renewable Sources of Energy</td><td rowspan="4">3</td><td rowspan="4">0</td><td rowspan="4">0</td><td rowspan="4">3</td></tr>
<tr><td>TE 1052</td><td>Fuel Cells and Hydrogen Technologies</td></tr>
<tr><td>TE 1053</td><td>Analysis of IC Engines</td></tr>
<tr><td>TE 1054</td><td>Jet Propulsion and Rocket Engineering</td></tr>
<tr><td>5</td><td>TE 106</td><td colspan="2">Thermal Engineering Lab</td><td>0</td><td>0</td><td>4</td><td>2</td></tr>
<tr><td>6</td><td>TE 107</td><td colspan="2">Computational Laboratory</td><td>0</td><td>0</td><td>4</td><td>2</td></tr>
<tr><td>7</td><td>TE 108</td><td colspan="2">Seminar I</td><td>0</td><td>0</td><td>2</td><td>1</td></tr>
<tr><td colspan="2"></td><td colspan="2">Total</td><td>15</td><td>3</td><td>10</td><td>23</td></tr>
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DEPARTMENT OF MECHANICAL ENGINEERING
R25 M.TECH (THERMAL ENGINEERING) SYLLABUS

II -SEMESTER

S. No	Course Code	Course Title		L	T	P	C
1	TE 201 (Core-1)	Computational Fluid Dynamics		3	1	0	4
2	TE 202 (Core-2)	Experimental Analysis and Instrumentation		3	1	0	4
	TE 203 (Core-3)	Advanced Finite Element Methods		3	1	0	4
3	Program Elective– III TE 204	TE 2041	HVAC Systems	3	0	0	3
		TE 2042	Fundamentals Of Microfluidics				
		TE 2043	Industrial Food Preservation				
		TE 2044	Industrial Hydraulics and Pneumatics				
4	Program Elective– IV TE 205	TE 2051	Thermal Management in EV Battery and Fuel Cell System	3	0	0	3
		TE 2052	Micro and Nano Scale Heat Transfer				
		TE 2053	Design of Heat Transfer Equipment				
		TE 2054	Introduction to Quantum Technologies				
5	TE 206	Computational Fluid Dynamics Lab		0	0	4	2
6	TE 207	Thermal Simulation Laboratory		0	0	4	2
7	TE 208	Seminar II		0	0	2	1
		Total		**15**	**3**	**10**	**23**

Note: Students are informed to complete Summer Internship (duration 8-10 weeks) at the end of the II Semester.

III- SEMESTER

S. No	Course Code	Course Title	L	T	P	C
1		Research Methodology and IPR/Swayam 12 Week MOOC Course RM&IPR	3	0	0	3
2		Summer Internship/Industrial Training (8-10 Weeks)	-	-	-	3
3		Comprehensive Viva	-	-	-	2
4		Dissertation Part - A	-	-	20	10
TOTAL			3	-	20	18

IV –SEMESTER

S. No	Course Code	Course Title	L	T	P	C
1		Dissertation Part - B	-	-	32	16
TOTAL			-	-	32	16

I Semester	ADVANCED HEAT TRANSFER	L	T	P	C
		3	1	0	4

Course Outcomes: At the end of the course, student will be able to

CO1	Develop the capacity to transform the physics of any heat conduction/thermal radiation problem into its equivalent mathematical model.
CO2	Demonstrate the ability to solve external forced and natural convection problems using analytical methods.
CO3	Develop the ability to analyze internal forced convection problems using analytical methods.
CO4	Apply the concepts of LMTD and NTU to solve Heat Exchanger Problems.
CO5	Evaluate radiant energy exchange in the presence of a participating medium.

UNIT-I:

INTRODUCTION: Review of basic concepts of conduction. Method of formulation: lumped, differential and integral formulations. Initial and boundary conditions

CONDUCTION:

Differential formulation of transient heat conduction problems with time independent boundary conditions in different geometries and their analytical solutions: method of separation of variables, method of Laplace transforms.

Differential formulation of steady two-dimensional heat conduction problems in different geometries and their analytical solutions: method of separation of variables, method of superposition.

UNIT II:

CONVECTION: Review of basics concepts and different non-dimensional numbers; Three-dimensional differential energy equation in Cartesian and Cylindrical coordinates.

FORCED CONVECTION: External flow:

External laminar forced convection for flow over a semi-infinite flat plate; Integral and similarity solutions for different thermal boundary conditions; Viscous dissipation effects in laminar boundary layer flow over a semi-infinite flat plate.

UNIT III:

FORCED CONVECTION: Internal flow:

Internal laminar forced convection: exact solutions for rectilinear flows, axisymmetric rectilinear flows, and axisymmetric torsional flows; Solution for fully developed flow through a pipe with different thermal boundary conditions, Flow in the thermal entrance region of a circular duct: Graetz solution for uniform velocity, Graetz solution for parabolic velocity profile.

UNIT IV:

FREE CONVECTION:

External laminar free convection: integral and similarity solutions for semi-infinite vertical plate with different thermal boundary conditions

HEAT EXCHANGERS: Classification, LMTD and NTU methods

UNIT V:

RADIATION:

Basic definitions, Radiant energy exchange between two differential area elements. Radiation shape factor: properties and algebra. Radiant energy exchange between two surfaces. Reradiating surfaces. Radiation Shield.

Radiant energy exchange in enclosures: enclosures composed of black and diffuse-grey surfaces. Electrical network analogy. Radiation in participating media: Radiative heat transfer equation, Radiant energy exchange in presence of absorbing and transmitting media, radiant energy exchange in presence of transmitting, reflecting, and absorbing media.

TEXT BOOKS:

1. Myers, G.E., 1971, Analytical methods in conduction heat transfer, McGraw Hill, New York.
2. Kays, W. M. and Crawford, M. E., 2005, Convective Heat and Mass Transfer, 3rd ed., McGraw Hill.
3. Howell, J.R., Mengüc, M.P., Daun, K., and Siegel, R., 2020, Thermal radiation heat transfer, CRC press, New York.

REFERENCES:

1. Arpaci, V.S.,1966, Conduction heat transfer, Addison-Wesley,Reading, Massachusetts.
2. Janna, W.S., 2018, Engineering heat transfer, CRC press, Boca Raton.
3. Fundamentals of Heat and Mass Transfer,5th Ed. / Frank P. Incropera/John Wiley
4. Sparrow, E.M., 2018, Radiation heat transfer, Routledge, New York.
5. Modest, M.F., and Mazumder, S., 2021, Radiative heat transfer, Academic press, New York.
6. Introduction to Heat Transfer/SK Som/PHI
7. Oostuizen, P. H. and Naylor, D., 1999, Introduction to Convective Heat Transfer Analysis, International ed., McGraw Hill.
8. Kakac, S. Yener, Y., and Pramuanjaroenkij. A., 2014, Convective Heat Transfer, 3rd ed., CRC Press

I Semester	ADVANCED FLUID MECHANICS	L	T	P	C
		3	1	0	4

Course Outcomes: At the end of the course, student will be able to

CO1	Understand the principles of Inviscid flow of incompressible fluid flow
CO2	Develop the capability to transform the physics of viscous fluid flow problems into its equivalent mathematical model.
CO3	Attain the ability to solve laminar boundary layer problems for the flow over a flat plate.
CO4	Develop an ability to solve fundamental problems of turbulent flows
CO5	Understand principles and techniques for solving compressible flow problems.

UNIT -I:
INVISCID FLOW OF INCOMPRESSIBLE FLUIDS: Lagrangian and Eulerian descriptions of fluid motion, Path lines, Streamlines, Streak lines, stream tubes – velocity of a fluid particle, types of flows, Equations of three-dimensional continuity equation, Stream and Velocity potential functions, Condition for irrotationality, circulation & vorticity, accelerations in Cartesian systems, normal and tangential accelerations.

UNIT -II:
VISCOUS FLOW: Derivation of Navier-Stoke's Equations for viscous compressible flow – Exact solutions to certain cases: Plain Poiseuille flow, Couette flow with and without pressure gradient, Hagen Poiseuille flow.

UNIT -III:
BOUNDARY LAYER CONCEPTS : Prandtl's contribution to real fluid flows – Prandtl's boundary layer theory, Boundary layer thickness for flow over a flat plate, Blasius solution – Approximate solutions, Von-Karman momentum integral equation for laminar boundary layer –– Expressions for local and mean drag coefficients for different velocity profiles.

UNIT- IV:
INTRODUCTION TO TURBULENT FLOW: Fundamental concept of turbulence – Time Averaged Equations – Boundary Layer Equations, Prandtl Mixing Length Model, Universal

Velocity Distribution Law: Van Driest Model, k-epsilon model, boundary layer separation and form drag – Karman Vortex Trail, Boundary layer control, lift on circular cylinders.
INTERNAL FLOW: Smooth and rough boundaries – Equations for Velocity Distribution and frictional Resistance in smooth and rough Pipes – Roughness of Commercial Pipes – Moody's diagram.

UNIT -V:
COMPRESSIBLE FLUID FLOW: Thermodynamic basics – Equations of continuity, Momentum and Energy, Acoustic Velocity, Derivation of Equation for Mach Number – Flow Regimes – Mach Angle – Mach Cone – Stagnation State, Area Variation, Property Relationships in terms of Mach number, Nozzles, Diffusers – Fanno and Raleigh Lines– Introduction to Normal and Oblique Compressible Shocks.

TEXT BOOKS:
1. L. Victor Steeter, Fluid Mechanics, 10th Edition, Tata McGraw-Hill, 1996.
2. Frank M. White, Fluid Mechanics, 8th Edition, McGraw-Hill Education, 2016.

REFERENCES:
1. Modi and Seth, Fluid Mechanics and Machines, Standard Book House
2. Pijush K. Kundu, Ira M. Cohen, and David R. Dowling, Fluid Mechanics, 5th Edition, Elsevier
3. David R. Dowling, Ira M. Cohen, and Pijush K. Kundu, Fluid Mechanics, 5th Edition, Cengage Learning, 2011
4. William S Janna, Fluid Mechanics, CRC Press, 3rd Edition, 2019
5. Y.A Cengel and J.M Cimbala, Fluid Mechanics, MGH, 4th Edition, 2018
6. Schlichting H, Boundary Layer Theory, Springer Publications, 9th Edition, 2017
7. Shapiro, Dynamics & Theory and Dynamics of Compressible Fluid Flow, 2nd Edition
8. William F. Hughes & John A. Brighton, Fluid Dynamics, TMH, 2nd Edition, 2018
9. K.L Kumar, Fluid Mechanics, S Chand & Co., 6th Edition, 2019

I Semester	AI&ML FOR MECHANICAL ENGINEERING	L	T	P	C
		3	1	0	4

Course outcomes: At the end of the course, student will be able to

CO1	Explain the basic concepts of artificial intelligence
CO2	Learn about the principles of supervised learning methods
CO3	Gain knowledge in unsupervised learning method and Bayesian algorithms
CO4	Get knowledge about neural networks and genetic algorithms.
CO5	Understand the machine learning analytics and apply deep learning techniques to mechanical engineering applications.

UNIT– I:

Introduction: Definition of Artificial Intelligence, Evolution, Need, and applications in real world. Intelligent Agents, Agents and Environments; Good Behaviour - concept of rationality, the nature of environments, structure of agents.

Introduction to Machine Learning (ML): Definition, Evolution, Need, applications of ML in industry and real-world, regression and classification problems, performance metrics, differences between supervised and unsupervised learning paradigms, bias, variance, overfitting and under fitting.

Supervised Learning: Linear regression, logistic regression, Distance-based methods, Nearest-Neighbours, Decision Trees, Support Vector Machines, Nonlinearity and Kernel Methods.

UNIT– II:

Unsupervised Learning: Clustering**,** K-means, Dimensionality Reduction, PCA and Kernel.
Bayesian and Computational Learning: Bayes theorem, concept learning, maximum likelihood of normal, binomial, exponential, and Poisson distributions, minimum description length principle, Naïve Bayes Classifier, Instance-based Learning- K-Nearest neighbour learning.

UNIT– III:

Neural Networks and Genetic Algorithms: Neural network representation, problems, perceptron, multilayer networks and backpropagation, steepest descent method, Convolutional neural networks and their applications Recurrent Neural Networks and their applications, LSTM, Transformers, Local vs Global optima, Genetic algorithms- binary coded GA, operators, convergence criteria.

UNIT– IV:

Deep Learning: Deep generative models, Deep Boltzmann Machines, Deep auto-encoders, Applications of Deep Networks.

Machine Learning Algorithm Analytics: Evaluating Machine Learning algorithms, Model, Selection, Ensemble Methods - Boosting, Bagging, and Random Forests.

UNIT– V

Applications to Mechanical Engineering: Modal analysis and damping prediction in mechanical structures, Crack detection and fatigue life estimation, Defect detection in casting and welding, Tool wear and Surface roughness prediction in CNC machining, Heat exchanger design optimization, fault diagnosis and energy optimization in refrigeration and air conditioning systems.

TEXT BOOKS:

1) Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach, 2/e, Pearson Education, 2010.

2) Tom M. Mitchell, Machine Learning, McGraw Hill, 2013.

3) Ethem Alpaydin, Introduction to Machine Learning (Adaptive Computation and Machine Learning), The MIT Press, 2004.

REFERENCES:

1) Elaine Rich, Kevin Knight and Shivashankar B. Nair, Artificial Intelligence, 3/e, McGraw Hill Education, 2008.

2) Dan W. Patterson, Introduction to Artificial Intelligence and Expert Systems, PHI Learning, 2012.

ONLINE RESOURCES:

https://www.tpointtech.com/artificial-intelligence-ai

https://www.geeksforgeeks.org/

I Semester	ADVANCED POWER PLANT ENGINEERING (Programme Elective I)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand Rankine cycle and suggest improvements possible in steam and gas turbines.
CO2	Analyze Power cycles and handle issues related to Power plants.
CO3	Explain advances in nuclear and MHD power plants
CO4	Understand the economic analysis of the Power Plants.
CO5	Explain how to combine different power plants.

UNIT – I: Rankine Cycle – performance – thermodynamic analysis of cycles, cycle improvements, super heaters, reheaters – condenser and feed water heaters – operation and performance – layouts, gas turbine cycles – optimization – thermodynamic analysis of cycles – cycle improvements – multi spool arrangement. Intercoolers, reheaters, regenerators – operation and performance – layouts.

UNIT- II: Binary and combined cycle – coupled cycles – comparative analysis of combined heat and power cycles – IGCC – AFBC/PFBC cycles – thermionic steam power plant.

UNIT- III: Overview of Nuclear power plants – radioactivity – fission process – reaction rates – diffusion theory, elastic scattering and slowing down – criticality calculations – critical heat flux – power reactors – nuclear safety. MHD and MHD – steam power plants.

UNIT- IV: Advantages of combined working – load division between power stations – storage type hydro-electric plant in combination with steam plant – run of river plant in combination with steam plant – pump storage plant in combination with steam or nuclear power plant – coordination of hydro-electric and gas turbine stations – coordination of hydro-electric and nuclear power station – coordination of different types of power plants. Air and water pollution –acid rains – thermal pollution – radioactive pollution –standardization – methods of control.

UNIT-V: Load curves–effects of variable load on power plant design and operation–peak load plant– requirements of peak load plants–cost of electrical energy–selection of type of generation–selection of generating equipment's–performance and operating characteristics of power plants.

TEXT BOOKS:

1. Nag, P.K., "Power Plant Engineering", Tata Mcgraw Hill Publishing Co Ltd, New Delhi, 1998.
2. Arora and Domkundwar, "A course in power Plant Engineering", DhanpatRai and CO, 2004.

REFERENCES:

1. Haywood, R.W, " Analysis of Engineering Cycles", 4th Edition, Pergamon Press, Oxford, 1991.
2. Wood, A.J., Wollenberg, B.F, "Power Generation, operation and control", John Wiley, New York, 1984.
3. Gill, A.B., " Power Plant Performance", Butterworths, 1984.
4. Lamarsh, J.R., "Introduction to Nuclear", Engg.2nd edition, AddisonWesley, 1983.

I Semester	CRYOGENIC ENGINEERING (Programme Elective I)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand the different fluid and material properties at low temperatures
CO2	Impart knowledge of the working principles of various cryo refrigerators, thermodynamic cycles for attaining low temperature, and gas separation and purification principles
CO3	Understand the fundamental principles of thermal design of storage vessels and insulation, transfer systems.
CO4	Understand the cool-down process and heat transfer in cryogenic fluids and the occurrence of two-phase flow and stratification in cryogenic systems.
CO5	Understand the importance of vacuum requirements in cryogenics, superconductivity, and special phenomena at very low-temperature engineering applications.

UNIT-I:

FLUID AND MATERIAL PROPERTIES AT LOW TEMPERATURE & APPLICATIONS OF CRYOGENICS:

Introduction to cryogenics: Cryogenic temperature scale, Properties of cryogenic fluids, super fluidity of He3 & He 4, properties of engineering materials at cryogenic temperatures, mechanical properties, thermal properties, electric & magnetic properties, super conducting materials.

Applications of cryogenic systems: Super conductive devices, space technology, space simulation, cryogenics in biology and medicine, food preservation and industrial applications, nuclear propulsions, chemical propulsions

UNIT-II:

CRYOGENIC GAS LIQUIFICATION:

Gas liquefaction systems: Introduction, thermodynamically ideal systems, Joule Thomson effect, liquefaction systems such as Linde Hampton, precooled Linde Hampson, Linde dual pressure, cascade system, Claude system, Kapitza system, Heyland systems using expanders, comparison of liquefaction systems and its performance evaluations.

UNIT-III:

CRYOGENIC AIR-SEPARATION:

Basics of Gas Separation, Ideal Gas Separation System, Gibbs Phase Rule, Phase Equilibrium Curves, Temperature Composition Diagrams, Raoult's Law, Gibbs – Dalton's Law, Distribution Coefficient, Enthalpy composition diagrams, Rectification Column Murphree efficiency, Theoretical Plate Calculations

UNIT-IV:

CRYOGENIC REFRIGERATOR AND CRYOCOOLERS:

Cryogenic Refrigeration System: Ideal isothermal and reversible isobaric source refrigeration cycles, Joule Thomson system, cascade or pre-cooled joule–Thomson refrigeration systems, expansion engine and cold gas refrigeration systems, Sterling refrigerators, Importance of regenerator effectiveness for the Sterling refrigerators, Gifford single volume refrigerator, Gifford double volume refrigerators analysis, Refrigerators using solids as working media: Magnetic cooling, magnetic refrigeration systems, thermal; valves, nuclear demagnetization, dilution refrigerator

UNIT-V:

CRYOGENIC FLUID STORAGE, INSTRUMENTATION, AND INSULATION:

Dewar vessel for cryogenic fluid storage, Construction, Inner vessel design, outer vessel design, Temperature measurements, pressure measurements, flow measurements, liquid level measurements, fluid quality measurements, Cryogenic insulation – expanded foams, gas filled & fibrous insulation, vacuum insulation, evacuated powder & fibrous insulation, Opacified powder insulation, multilayer insulation, comparison of performance of various insulations.

TEXT BOOKS:

1. Barron, R., 1985, Cryogenic Systems, SI version, Oxford university press.
2. Scott, R. B., 1962, Cryogenic Engineering, D. Van Nostrand Company.

REFERENCES:

1. Timmerhaus, K. D. and Flynn, T. M., 1989, Cryogenic Process Engineering, Plenum Press.
2. Vance, R. W., and Duke, W. M., 1962, Applied Cryogenic Engineering, John Wiley.
3. Sittig, M., 1963, Cryogenics Research and Applications, D. Van Nostrand Company.
4. Hands, B.A., 1986, Cryogenic engineering, Academic press.
5. Flynn, T. M., 2005, Cryogenic Engineering, Marcel Dekker Inc., New York.

I Semester	TURBO MACHINES (Programme Elective I)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand the fundamentals of Turbo machines to evaluate the performance.
CO2	Apply the knowledge in the design of steam nozzles.
CO3	Understand the basics of gas dynamics and centrifugal compressors.
CO4	Apply the knowledge in the design of axial flow compressors.
CO5	Apply the knowledge in the design of axial flow turbines.

UNIT – I:

FUNDAMENTALS OF TURBO MACHINES:

Classification, Application Thermodynamic analysis; Isentropic flow, Energy transfer; Efficiencies; static and Stagnation conditions; continuity equation; Euler's flow through variable cross-sectional area; unsteady flow in turbo machines.

UNIT –II:

STEAM NOZZLES: Effect of back – pressure on the analysis; Design of nozzles. Steam Turbines of C & C –D nozzles :Impulse Turbines: work done and velocity triangles; Efficiencies; Constant Reaction Blading; Design of blade passages, angles and height; Secondary flow; leakage losses; Thermodynamic analysis of steam turbines.

UNIT – III:

GAS DYNAMICS: Fundamentals thermodynamic concepts; Isentropic conditions; Mach number and Area – Velocity relation; Dynamic pressure; normal shock relations for perfect gas; supersonic flow, oblique shock waves ; normal shock recovery ; detached shocks ; Aerofoil theory.

Centrifugal Compressor: Types; Velocity triangles and efficiencies; Blade passage design; Diffuser and pressure recovery; slip factor; stanitz and stodolas formulae; Effect of inlet Mach number; Pre-whirl; performance.

UNIT – IV:

AXIAL FLOW COMPRESSORS: Flow analysis, work and velocity triangles ; Efficiencies; Thermodynamic analysis; stage pressure rise ; Degree of reaction ; stage loading ; general design, effect of velocity incidence ; performance. Cascade Analysis: Geometry and Terminology; Blade forces, Efficiency; losses; free and forced vortex blades.

UNIT – V:

AXIAL FLOW GAS TURBINES: Work done; velocity triangles and efficiencies; thermodynamic flow analysis; degree of reaction; Zweifels relation; Design cascade analysis – Soderberg – Hawthrone – ainley-correlations; secondary flow; Free-vortex blades; Blade angles for variable degree of reaction; Actuator disc theory; stresses in blades; Blade assembling; materials and cooling of blades; performance; Matching of compressor and turbine; off-design performance.

TEXT BOOKS:

1. Shepherd, I. G., Fundamentals of Turbomachinery, 2nd Edition, John Wiley & Sons, 2005.

2. Yahya, S. M., Elements of Gas Dynamics, 2nd Edition, PHI Learning Pvt. Ltd., 2013.

REFERENCES:

1. Fluid Mechanics and Thermodynamics of Turbomachinery, Dixon, S.L, Elsevier, 2014, 7th Edition.
2. Gas Turbine Theory, Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Pearson Prentice Hall, 2017, 7th Edition.
3. G. Gopalakrishnan and D. Prithviraj, Practice on Turbomachines, SciTech Publishers, Chennai.
4. H Cohen, GFC Rogers and HIH Saravanamuttoo, “Gas Turbine Theory”, Pearson Education, 2000.

I Semester	ADVANCED THERMODYNAMICS & COMBUSTION (Programme Elective I)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand how to use the laws of thermodynamics to analyze complete thermodynamic systems and calculate energy and entropy balances.
CO2	Apply thermodynamic property relations to determine different thermodynamic parameters.
CO3	Identify and apply thermodynamic principles to determine thermodynamic properties of mixtures
CO4	Understand the Phase equilibrium of mixtures.
CO5	Apply the first and second law of thermodynamics to chemical reactions

UNIT-I

AVAILABILITY AND IRREVERSIBILITY: Quality of Energy, available and unavailable energy, availability, surrounding work, reversible work and irreversibility, availability in a closed system, availability in a steady process in an open system, second law efficiencies of processes, second law efficiency of cycles and exergy balance equations.

UNIT-II

THERMODYNAMIC PROPERTY RELATIONS: Helmholtz and Gibbs Functions, two Mathematical Conditions for Exact Differentials, Maxwell Relations, Clapeyron Equation, Relations for Changes in Enthalpy, Internal Energy and Entropy, Specific Heat Relations, Generalized Relations/Charts for Residual Enthalpy and Entropy, Gibbs Function at zero Pressure: A Mathematical Anomaly, Fugacity, Fugacity Coefficient and Residual Gibbs Function, The Joule, Thomson Coefficient and Inversion Curve, Thermodynamic similarity.

UNIT-III

GAS MIXTURES: Mixtures of ideal Gases, Gas-Vapor Mixtures, Application of First Law to Psychometric Processes, Real Gas Mixtures.

THERMODYNAMIC RELATIONS FOR REAL MIXTURES: Partial Properties, Relation for Fugacity and Fugacity Coefficient in Real Gas Mixtures, Relations for Activity and Activity Coefficient in Real Liquid Mixtures/Solutions.

UNIT-IV

PHASE EQUILIBRIUM: VAPOR LIQUID EQUILIBRIUM OF MIXTURES: Phase Diagrams for Binary Mixtures, Vapor, Liquid Equilibrium in Ideal Solutions, Criteria for Equilibrium, Criterion for phase Equilibrium, Calculation of Standard State Fugacity of Pure Component, Vapor Liquid Equilibrium at Low to Moderate Pressures, Determination of Constants of Activity Coefficient Equations, Enthalpy Calculations.

UNIT-V

CHEMICAL REACTIONS AND COMBUSTION: Thermochemistry, Measures of Composition in Chemical Reactions, Application of First Law of Thermodynamics to chemical Reactions, the Combustion Process-Standard Heat/Enthalpy of Combustion, Reactions at actual Temperatures, adiabatic Flame Temperature, Entropy Change of Reacting Systems, Application of second Law of Thermodynamics to chemical Reactions, chemical equilibrium-Advancement of Chemical Reactions, Equilibrium Criterion in Chemical Reactions, equilibrium Constant and Law of Mass Action, Equilibrium Constant for Gas Phase Reactions in the standard state.

TEXT BOOKS:

1. P.K.Nag, Basic and Applied Thermodynamics, 2nd Edition, Tata McGraw-Hill, 2019.
2. J.P Holman, Thermodynamics, 10th Edition, McGraw Hill, 2017.
3. CP Arora, Thermodynamics: An Engineering Approach, 5th Edition, McGraw Hill Education (India) Pvt. Limited, 2016.

REFERENCES:

1. Moran, M. J., Shapiro, H. N., Boettner, D. D., and Bailey, M. B., 2018, Fundamentals of Engineering Thermodynamics, 9th ed., Wiley.
2. Cengel, Y. A., 2010, Introduction to Thermodynamics and Heat Transfer, 2nd ed., McGraw-Hill Education.
3. Bejan, A., 2016, Advanced Engineering Thermodynamics, 4th ed., Wiley. 5. Nag, P.K, 2017, Engineering Thermodynamics, 6th ed., McGraw Hill Education.
4. Sonntag, R. E, Borgnakke, C and Wylen, G. J. V., and., 2023, Fundamentals of Classical thermodynamics, 6th ed., Wiley Eastern Ltd.
5. Jones, J. B. and Hawkins, G. A., 1986, Engineering Thermodynamics, John Wiley Sons.

I Semester	RENEWABLE SOURCES OF ENERGY (Programme Elective II)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Identify the renewable energy sources, their utilization, and storage and evaluate the energy conversion from ocean thermal energy.
CO2	Understand the basic concepts of solar radiation and analyze the solar thermal systems for their utilization and the principle of working of solar cells.
CO3	Understand the Wind energy systems and its components with basic working principles.
CO4	Analyze Bio energy and Bio mass systems.
CO5	Narrate the importance and potential of geo thermal energy and Integrated power generation systems.

UNIT-I

INTRODUCTION: Energy and development, energy demand and availability, energy crisis, conventional and non-conventional sources, renewable and non-renewable energy resources, environmental impact of conventional energy usage, basic concepts of heat and fluid flow useful for energy systems.

ENERGY FROM THE OCEANS: OTEC systems, open and closed types; Wave energy conversion systems; Tidal energy conversion systems.

UNIT II

SOLAR ENERGY: Solar radiation at the earth's surface – solar radiation measurements – estimation of average solar radiation - solar thermal flat plate collectors - concentrating collectors – solar thermal applications - heating, cooling, desalination, drying, cooking, etc – solar thermal electric power plant - principle of photovoltaic conversion of solar energy, types of solar cells - Photovoltaic applications: battery charger, domestic lighting, street lighting, water pumping - solar PV power plant – Net metering concept.

UNIT III

WIND ENERGY: Nature of the wind – power in the wind – factors influencing wind – wind data and energy estimation - wind speed monitoring - wind resource assessment - Betz limit - site selection - wind energy conversion devices - classification, characteristics, applications – offshore wind energy – Hybrid systems - safety and environmental aspects – wind energy potential and installation in India - Repowering concept.

UNIT IV

BIO-ENERGY: Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - direct combustion – biomass gasification - pyrolysis and liquefaction – biochemical conversion - anaerobic digestion - types of biogas Plants - applications - alcohol production from biomass – bio diesel production – Urban waste to energy conversion - Biomass energy programme in India.

UNIT-V:

MICRO AND SMALL HYDRO ENERGY SYSTEMS: Resource assessment of micro and small hydro power, micro, mini and small hydro power systems, economics, pump as turbine, special engines for low heads, velocity head turbines, hydrams, water mills.

GEOTHERMAL ENERGY SYSTEMS: Vapor dominated, liquid dominated and petrothermal systems; Hybrid systems.

INTEGRATED ENERGY SYSTEMS: Concept of integration of conventional and non-conventional energy resources and systems; integrated energy system design and economics.

TEXT-BOOKS:

1. Non conventional Energy Resources, B.H.Khan, Tata McGraw Hill, New Delhi, 2017, 3rd edition.
2. Energy Technology: Non-Conventional, Renewable and Conventional, S.Rao and B.B.Parulekar, Khanna Publishers, 2010, 1st Edition.

REFERENCES:

1. Duffie, J.A. and Beckman, W.A., “Solar Engineering of Thermal Processes”, John Wiley., 2006
2. Bungay, H.R., “Energy, the Biomass Option”, John Wiley. , 1981
3. Fowler, K.M., “Energy &Environment”,McGraw Hill. , 1984
4. Sukhatme, S.P. and Nayak, J.K., ”Solar Energy: principles of thermal collection and storage”, McGraw Hill., 2009
5. Boyle, G., “Renewable Energy – Power for a Sustainable Future”, 2nd Ed., Oxford University Press., 2010.

I Semester	FUEL CELLS AND HYDROGEN TECHNOLOGIES (Programme Elective II)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand fuel cell fundamentals
CO2	Demonstrate the operation of different fuel cells
CO3	Analyse the performance of PEM fuel cell system
CO4	Understand the Production, Storage and Transportation systems of Hydrogen.
CO5	Understand the applications of Hydrogen in Stationary and Automotive applications.

UNIT-I:
Introduction to Fuel Cells – Fuel cell concept - key components - physical and chemical phenomena in fuel cells - advantages and disadvantages of fuel cells – different types of fuel cells and their characteristics – fuel cells for stationary applications – fuel cell vehicles.

UNIT-II
Thermodynamic analysis – systematic enthalpy change of a reacting system – systematic Gibbs free energy – change of a reacting system – ideal efficiency of the energy conversion – energy balance in fuel cells.

UNIT-III:
Electrochemistry – Nernst equation, relation of the fuel consumption versus output – stoichiometric coefficients and utilization percentages of fuels and oxygen – mass flow rate calculation for fuel and oxygen in single cell and fuel cell stack – total voltage and current for fuel cells in parallel and series connection – over-potential and polarizations.

UNIT-IV:
DMFC operation scheme – general issues-water flooding and water management - polarization in PEMFC - optimization design of PEMFC – case studies.
Hydrogen economy – Introduction to hydrogen economy - production, storage and transportation systems – hydrogen from fossil fuels – electrolysis of water – thermochemical cycles – baseline and alternative thermochemical cycles.

UNIT-V:
Hydrogen utilization – Hydrogen for stationary and automotive applications – transmission and infrastructure requirements – safety and environmental impacts - economics of transition to hydrogen systems – case studies.

TEXT BOOKS:

1. Vishwanathan B. and AuliceScibioh, "Fuel cells: Principles and Applications", University Press, 2006.
2. Ram B. Gupta, "Hydrogen Fuel: Production, Transport and Storage", CRC Press.

REFERENCES:

1. Peter Hoffman, "Tomorrow's Energy – Hydrogen Fuel cells and the Prospects for Cleaner Planet", MIT, 2002.
2. Prashukumar G.P., "Hydrogen – A Fuel for Automatic Engines"" ISTE, 1999.
3. Hart A.B. and Womack G.J., "Fuel Cells – Theory and Applications", Chapman and Hall, 1967.
4. Young G.J., "Fuel Cells", Rein hold publishing Corp., 1960.
5. Veziroglu T., "Hydrogen Energy", Springer publishing, 1975.

I Semester	ANALYSIS OF IC ENGINES (Programme Elective II)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Analyze mixture systems for IC engines and describe different fuel supply systems in spark ignition and compression ignition engines.
CO2	Summarize the methods used to improve engine performance and estimate performance parameters.
CO3	Analyze the different fuels for SI and CI Engines.
CO4	Analyze the different combustion phenomenon in SI and CI engines.
CO5	Understand the basics of EV and Hybrid Engines.

UNIT-I:

Working principle - Constructional details - Classification and application of different types of I.C. engines - Two stroke engines - Wankel and other rotary engines - Stirling engine.

Mixture preparation systems for SI and CI engines – Carburetor – MPFI – Diesel fuel supply systems – fuel pumps - fuel injectors – unit injector - CRDI - Combustion chambers - Ignition.

Lubrication and Cooling Systems - Speed Governing systems - Intake and exhaust systems. Supercharging methods - Turbocharger matching - Aerothermodynamics of compressors and turbines.

UNIT-II:

Engine testing and performance – Effects of engine design and operating parameters on performance and emissions; Pollution formation in SI and CI engines - Factors affecting emissions - Control measures for evaporative emissions - Thermal reactors and catalytic converters.

Engine modifications (EGR) to reduce emissions - Instrumentation to measure pollutants - Emission standards and testing - Review of basic thermodynamics and gaseous mixtures – Stoichiometry - Adiabatic flame temperature - First and Second Laws of Thermodynamics applied to combustion - Equilibrium sproducts of combustion.

UNIT-III:

Fundamentals of combustion kinetics – Elementary reaction rates. General characteristics of combustion flame – detonation – deflagration - Factors affecting flame velocity and thickness – Quenching - Flammability – Ignition - Flame stabilization Laminar premixed flames - Laminar diffusion flames - Turbulent premixed flames.

Fuels and their properties - Equivalence ratio – Self ignition temperature – Ignition lag - Role of fuel in engine combustion –Fuels for SI & CI engines – Octane number – Cetane number - Combustion generated pollutants.

UNIT-IV:
Normal combustion in SI Engines: Thermodynamic Analysis, Flame structure and speed, cyclic variations in combustion. Factors affecting combustion in SI engines – Effect of engine variables on flame propagation and ignition lag - Knocking - Effect of variables on knock – Detection of knock –Control of Knock - Pre-ignition - Normal combustion in CI Engines – Analysis of cylinder pressure data – Direct Injection and Indirect Injection, Fuel spray behavior - Variables affecting delay period - Factors affecting combustion in CI engines.

UNIT-V:

Electric Vehicles: Introduction: History of EVs, EV system, basic structure- Electric vehicle drivetrain-advantages and limitations, Components of EV Battery run EVs and Electric Motor run EVs- Brief treatment on types of electric machines for EVs (Power-Torque characteristics), regenerative braking system.

Hybrid Vehicles: Configurations of hybrids, advantages and limitations- basic structure of series, parallel and series-parallel configurations.

TEXTBOOKS:

1. Heywood, J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, 1989.
2. Stephen R. T., An Introduction to Combustion, McGraw-Hill International Editions, 1996.
3. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Mehrdad Ehsani, Yimin Gao, Stefano Longo and Kambiz Ebrahimi, CRC Press, 2018, II Edition.

REFERENCES:

1. Kuo, K. K., Principles of Combustion, John Willey & Sons, 1986.
2. Strehlow, R. A., Combustion Fundamentals, McGraw-Hill, 1985.
3. Mukunda, H. S., Understanding Combustion, Macmillan India Ltd., 1992.
4. Ashley S. C., Thermodynamic Analysis of Combustion Engines, John Wiley, 1979.
5. Maleev, M. L., Internal Combustion Engines, Second edition, McGraw-Hill, 1989.
6. Mathur, M. L. and Sharma, R. P., Internal Combustion Engines, Dhanpath Rai & Sons, 2005.
7. Electric vehicle technology explained, John Lowry and James Larmine, John Wiley and Sons, 2012.

I Semester	JET PROPULSION AND ROCKET ENGINEERING (Programme Elective II)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand the ideal and real thermodynamic cycles of air-breathing engines and Industrial gas turbines
CO2	Design the blading, study the velocity triangles and estimate the performance of centrifugal and axial flow compressors.
CO3	Understand the combustion process and design the combustion chamber of a gas Turbine.
CO4	Design the blading, study the velocity triangles and estimate the performance of axial and radial in-flow turbines
CO5	Analyse the off-design performance and matching of the components of a gas turbine

UNIT - I: TURBO JET PROPULSION SYSTEM: Gas turbine cycle analysis – layout of turbo jet engine. Turbo machinery- compressors and turbines, combustor, blade aerodynamics, engine off design performance analysis. Flight Performance: Forces acting on vehicle – Basic relations of motion – multi stage vehicles.

UNIT - II: PRINCIPLES OF JET PROPULSION AND ROCKETRY: Fundamentals of jet propulsion, Rockets and air breathing jet engines – Classification – turbo jet , turbo fan, turbo prop, rocket (Solid and Liquid propellant rockets) and Ramjet engines. Nozzle Theory and Characteristics Parameters: Theory of one dimensional convergent – divergent nozzles – aerodynamic choking of nozzles and mass flow through a nozzle – nozzle exhaust velocity – thrust, thrust coefficient, Supersonic nozzle shape, non-adapted nozzles, summer field criteria, departure from simple analysis – characteristic parameters – characteristic velocity - specific impulse - total impulse - relationship between the characteristic parameters - nozzle efficiency, combustion efficiency and overall efficiency.

UNIT - III: AERO THERMO CHEMISTRY OF THE COMBUSTION PRODUCTS: Review of properties of mixture of gases – Gibbs – Dalton laws – Equivalent ratio, enthalpy changes in reactions heat of reaction and heat of formation – calculation of adiabatic flame temperature and specific impulse – frozen and equilibrium flows. Solid Propulsion System: Solid propellants – classification, homogeneous and heterogeneous propellants, double base propellant compositions and manufacturing methods. Composite propellant oxidizers and binders. Effect of binder on propellant properties. Burning rate and burning rate laws, factors influencing the burning rate, methods of determining burning rates.

UNIT - IV: Solid propellant rocket engine – internal ballistics, equilibrium motor operation and equilibrium pressure to various parameters. Transient and pseudo equilibrium operation, end burning and burning grains, grain design. Rocket motor hard ware design. Heat transfer considerations in solid rocket motor design. Ignition system, simple pyro devices. Liquid Rocket Propulsion System: Liquid propellants – classification, Mono and Bi propellants, Cryogenic and storage propellants, ignition delay of hypergolic propellants, physical and chemical characteristics of liquid propellant. Liquid propellant rocket engine – system layout, pump and pressure feed systems, feed system components. Design of combustion chamber, characteristic length, constructional features, and chamber wall stresses. Heat transfer and cooling aspects. Uncooled engines, injectors – various types, injection patterns, injector characteristics, and atomization and drop size distribution, propellant tank design.

UNIT - V: RAMJET AND INTEGRAL ROCKET RAMJET PROPULSION SYSTEM: Fuel rich solid propellants, gross thrust, gross thrust coefficient, combustion efficiency of ramjet engine, air intakes and their classification – critical, super critical and sub-critical operation of air intakes, engine intake matching, classification and comparison of IIRR propulsion systems.

TEXT BOOKS:

1. Mechanics and Dynamics of Propulsion/ Hill and Peterson/John Wiley & Sons
2. Rocket propulsion elements/Sutton/John Wiley & Sons/8th Edition

REFERENCES:

1. H Cohen, GFC Rogers and HIH Saravanamuttoo, "Gas Turbine Theory", Pearson Education, 2000.
2. Gas Turbines/Ganesan /TMH
3. Gas Turbines & Propulsive Systems/Khajuria & Dubey/Dhanpat Rai & Sons
4. Rocket propulsion/Bevere/
5. Jet propulsion /Nicholas Cumpsty/
6. Elements of Gas Turbine Propulsion/Jack D. Mattingly/TMH
7. Turbines, Compressors and Fans/S M Yahya /MGH

I Semester	THERMAL ENGINEERING LABORATORY	L	T	P	C
		0	0	4	2

Course Outcomes: At the end of the course, student will be able to

CO1	Estimate the thermal conductivity of liquids and gases.
CO2	Evaluate the performance of Solar Still and Flat Plate Collector.
CO3	Understand Wind Tunnel Equipment and determine pressure distribution and drag forces.
CO4	Estimate the performance of Air Compressor and VCR system.
CO5	Evaluate the performance of Variable compression Engine.

LIST OF THE EXPERIMENTS:

1. To fabricate and calibrate a thermocouple and illustrate its use in the temperature measurement.
2. To determine the LMTD, Effectiveness and Heat Transfer rate of a Shell and Tube Heat Exchanger.
3. To determine the Performance of a Solar Flat Plate Collector.
4. To determine the Performance of a Solar Still.
5. To determine the thermal conductivity of liquids and gases.
6. To determine the heat transfer rate in drop and film wise condensation.
7. To determine the critical heat flux of a wire.
8. To conduct the performance test on four stroke variable compression ratio diesel engine.
9. To conduct the performance test on a reciprocating air compressor
10. To determine the coefficient of performance in a Vapour Compression Refrigeration system.
11. To conduct the flame propagation analysis of gaseous fuels.
12. To Evaluate the engine friction by Motoring/Retardation Test on an IC Engine.
13. Determination of Pressure Distribution over a Symmetric Aero foil.
14. Determination of Drag over the Sphere with different angle of attacks.

I Semester	COMPUTATIONAL LABORATORY	L	T	P	C
		0	0	4	2

Course Outcomes: At the end of the course, student will be able to

CO1	Develop essential programming skills in computer programming concepts like data types, containers apply the basics of programming in the MATLAB &Python language.
CO2	Solve the different methods for linear, non-linear and differential equations
CO3	Develop MATLAB & Python Codes to solve different Numerical Methods.

TO DETERMINE:

1. Roots of the equations using (i) Bisection method, (ii) Regula falsi method and (ii) Newton Raphson method.
2. Solution of Simultaneous Linear equations using (i) Gauss Elimination, (ii) Jacobi's, and (iii) Gauss-Seidel iterative methods.
3. Determination of Eigen values and Eigen vectors of a matrix.
4. Numerical Integration using (i) Trapezoidal method, (ii) Simpson 1/3rd and (iii)Simpson's 3/8th rule.
5. Solution of Ordinary differential equations using (i) Eulers and (ii) Runge-Kutta methods.
6. Solution of Tri-Diagonal Matrix.
7. Best fit using the principle of least squares.

[Above experiments must complete using MATLAB and Python Code]

I Semester	SEMINAR - I	L	T	P	C
		0	0	2	1

II Semester	COMPUTATIONAL FLUID DYNAMICS	L	T	P	C
		3	1	0	4

Course Outcomes: At the end of the course, student will be able to

CO1	Differentiate between different types of partial differential equations that govern fluid dynamics, such as conservation, continuity, momentum and energy equations.
CO2	Understand and Implement Finite Difference methods for Elliptical, Parabolic and Hyperbolic form of Partial Differential Equations.
CO3	Discretize the equations using Finite Volume Method applied to Diffusion and Convective-Diffusion Equations and understand the solution methodology.
CO4	Discretize the governing equations applied to Steady and Unsteady flows using Finite Volume Method.
CO5	Develop the ability for FEM discretization for simple one dimensional steady and unsteady problems in fluid flow and heat transfer.

UNIT-I:
A brief overview of the basic conservation equations for fluid flow and heat transfer, Boundary Conditions, classification of partial differential equations and pertinent physical behaviour, parabolic, elliptic and hyperbolic equations, role of characteristics. Over-View of Finite Element, Finite Difference and Finite Volume Methods.
Finite Difference Method: Derivation of Finite Difference Equations, Accuracy of Finite Difference Equations. Numerical Errors: Round-off, Truncation and Discretization Errors. Solution of discretized equations: Direct and Indirect or iterative methods, TDMA algorithm.
Elliptical Equations: Finite Difference Formulations, Iterative Solution Methods, Examples.
UNIT-II:
Parabolic Equations: Explicit Schemes and Von-Neumann Stability Analysis, Implicit Schemes, ADI Schemes, Approximate Factorization, Fractional Step Methods, Examples.
Hyperbolic Equations: Explicit schemes and Von-Neumann stability analysis, Implicit schemes, multi-step methods, nonlinear problems, second order one-dimensional wave equations, Examples.
UNIT-III:
In-compressible Viscous Flows via FDM: Artificial Compressibility Method, Pressure Correction Methods and Vortex Methods, Examples.

TREATMENT OF COMPRESSIBLE FLOWS: Potential equation, Eluer equations, Navier Stokes system of equations, flow-field, dependent variation methods, boundary conditions. **UNIT-IV:**

FINITE VOLUME METHOD-I: DIFFUSION PROBLEMS: Solutions for 1-D and 2-D steady-state diffusion problems.

CONVECTION-DIFFUSION PROBLEMS: Solutions using Central Differencing Scheme, Upwind differencing scheme, Hybrid differencing Scheme, Power Law scheme, Higher order differencing schemes, TVD schemes.

UNIT-V:

FINITE VOLUME METHOD-II: STEADY FLOWS: Staggered grid, SIMPLE, SIMPLER, SIMPLEC and PISO algorithms.

UNSTEADY FLOWS: Solutions for Transient 1-D and 2-D Heat Conduction, Transient convection-diffusion problems, QUICK Scheme, Solutions using Transient SIMPLE and Transient PISO algorithms.

TEXT BOOKS:

1. Chung, T. J., 2010, Computational Fluid Dynamics, 2nd ed., Cambridge University Press.
2. Versteeg, H. K., and Malalasekera, W., 2007, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, 2nd ed., Pearson Education Limited.

REFERENCES:

1. Patankar, S. V., 2017, Numerical Heat Transfer and Fluid Flow, Special Indian ed., CRC Press.
2. Muralidhar K., and Sundararajan T. (Editors), 2017, Computational Fluid Flow and Heat Transfer, 2nd ed. tenth reprint, Narosa.
3. Anderson Jr., J. D., 2017, Computational Fluid Dynamics: The Basics with Applications, Indian ed., McGraw Hill Education.

II Semester	EXPERIMENTAL ANALYSIS AND INSTRUMENTATION	L	T	P	C
		3	1	0	4

Course Outcomes: At the end of the course, student will be able to

CO1	Post-process the experimental data employing the standard statistical tools.
CO2	Analyze First and Second Order Systems applied different Thermal Systems.
CO3	Estimate uncertainties associated with the measurements.
CO4	Employ the knowledge for carrying out experiments in research labs and industries.
CO5	Design novel techniques for measurements of thermo-physical properties.

UNIT-I:

Concepts in dynamics measurements; system response; error analysis; uncertainty analysis; calibration; statistical analysis; probability distributions; goodness of data; method of least squares and multivariable regression.

UNIT-II:

Process control: Introduction and need for process control principles, transfer functions, block diagrams, signal flow graphs, open and closed-loop control systems – Analysis of First & Second-order systems with examples of mechanical and thermal systems. Control System Evaluation – Stability, steady-state regulations, and transient regulations.

Data acquisition systems: A to D and D to A convertors

UNIT-III:

Temperature measurements – by mechanical effects, electrical effects; thermistors; liquid crystal thermography; thermocouples – types, laws of thermocouple, thermopile, transient response of thermal systems; temperature measurement in cryogenics.

Pressure measurements - bourdon-tube gage, diaphragm and bellows gage; inductive, piezoelectric and capacitative transducers; McLeod gage; Knudsen gage; ionization gage.

UNIT-IV:

Flow measurements – flow obstruction meters – venturi, orifice, nozzle meters; turbine meters; coriolis flow meters; ultrasonic flow meters; magnetic flow meters. Hot-wire and hot-film anemometry; Laser Doppler Anemometer.

Acoustic measurements – microphones and sound lever meters. Flow visualization - schlieren; shadowgraph; interferometer.

UNIT-V:

Measurement of thermal and physical properties – viscosity; thermal conductivity of solids and fluids – steady and unsteady state measurements; thermal conductivity of low-conducting and metallic solids; measurement of specific heat of solids and fluids; measurement of derived quantities – heat flux; heat transfer coefficient; measurement of calorific values, humidity.

Thermal radiation measurements – emissivity; reflectivity and transmissivity; pyrometry; solar radiation measurements, Introduction to IR emission measurements.

TEXTBOOKS:

1. Eckert, E.R.G., and Goldstein, R.J., 1976, Measurements in Heat Transfer, 2nd ed. McGraw Hill.
2. Holman, J.P., 2012, Experimental Methods for Engineers, 8th ed., McGraw Hill.

REFERENCES:

1. Beckwith, T.G., Marangoni, R.D., and Lienhard V, J.H., 2007, Mechanical Measurements, 6th ed., Pearson Prentice Hall.
2. Sirohi, R.S., and Radha Krishna, H.C., 1991, Mechanical Measurements, 3rd ed., New Age International.
3. Venkateshan, S.P., Mechanical Measurements; 2nd ed., John Wiley & Sons.

II Semester	ADVANCED FINITE ELEMENT METHODS	L	T	P	C
		3	1	0	4

COURSE OUTCOME: At the end of this course, the students will be able to

CO1	Synthesise information and ideas for use in the evaluation process.
CO2	Develop governing equations of mechanical systems using domain knowledge and mathematical principles and apply principles of variation and integral forms of solution to formulate finite element problem.
CO3	Analyse and build FEA model for complex engineering problems.
CO4	Perceive the fundamental theory of the finite elements.
CO5	Develop skills to model the behavior of structures under mechanical and thermomechanical loads

UNIT - I:

Finite Element Formulation: Introduction, Weighted Residual Method, weak form of WR statement, Principle of stationary total potential (PSTP), Rayleigh – Ritz Method.

UNIT – II:

One Dimensional Finite Element Analysis: General form of total potential for 1-D and finite element equations, Linear bar element, Quadratic bar element, Cubic bar element, Higher order elements, Beam Element, Frame elements, Applications of one dimensional elements, Natural co-ordinates and Co-ordinate transformation, Numerical integration.

UNIT – III:

Two Dimensional Finite Element Analysis: Introduction, Simple three noded triangular element, four noded rectangular element, six noded triangular element, serendipity and higher order 2-D elements.

UNIT – IV:

Axisymmetric elements, Structural mechanics applications of 2-D and axisymmetric elements, Incorporation of Boundary conditions, Solution of static Equilibrium Equations. Heat transfer applications in 2-D.

UNIT – V:

Iso-parametric element; linear and trilinear elements; Numerical Integration; Gaussian quadrature; Shape functions and their derivatives; 2D and 3D boundary value problems: Trial solutions and weighting functions; Strong form, weak form, boundary conditions; Finite element spatial discretization; Examples from Conduction Heat Transfer and Flows of Viscous Incompressible Fluids.

TEXT BOOKS:

1. Textbook of Finite Element Analysis, P Sheshu, PHI, 2004.
2. Finite Element Methods for Engineers, U S Dixit, Cengage Learning, 2011.
3. Finite element methods by Chandrubatla & Belagondu.

REFERENCES:

1. Concepts and Application of Finite Elements Analysis, Cook, Malkus and Plesha, Wiley.
2. Finite Element Method, J N Reddy, McGraw Hill International Edition.

II Semester	HVAC SYSTEMS (Programme Elective III)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand the fundamentals of Psychrometry of Air-conditioning processes.
CO2	Apply human comfort indices and comfort charts to design indoor conditions of HVAC systems.
CO3	Estimate heating and loads for buildings according to ASHRAE procedures and standards.
CO4	Design and evaluate a complete air distribution system including fan, duct, and installation requirements for a typical HVAC system.
CO5	Understand the basic principles and applications of Heat Pumps.

UNIT-I:

INTRODUCTION: Brief history of air conditioning and impact of air conditioning. HVAC systems and classifications,

PSYCHROMETRY OF AIR CONDITIONING PROCESSES: Thermodynamic properties of moist air, Important Psychrometry properties, Psychrometric chart; Psychrometric process in air conditioning equipment, applied Psychrometry, air conditioning processes, air washers.

UNIT-II:

COMFORT AIR CONDITIONING: Thermodynamics of human body, metabolic rate, energy balance and models, thermoregulatory mechanism. Comfort & Comfort chart, Effective temperature, Factors governing optimum effective temperature, Design consideration. Selection of outside and inside design conditions.

UNIT-III:

HEAT TRANSFER THROUGH BUILDING STRUCTURES: Solar radiation; basic concepts, sun-earth relationship, different angles, measurement of solar load, Periodic heat transfer through walls and roofs. Empirical methods to calculate heat transfer through walls and roofs using decrement factor and time lag method. Infiltration, stack effect, wind effect. CLTD/ETD method – Use of tables, Numerical and other methods, Heat transfer through fenestration – Governing equations, SHGF/SC/CLF Tables

UNIT-IV:

VENTILATION SYSTEM: Introduction- Fundamentals of good indoor air quality, need for building ventilation, Types of ventilation system, Air Inlet system. Filters heating & cooling equipment, Fans, Duct design, Grills, Diffusers for distribution of air in the workplace, HVAC interface with fire and gas detection systems - system requirements, devices and their functioning.

UNIT-V:

LOAD CALCULATIONS: Types of air-conditioning systems, General consideration, internal heat gains, system heat gain, cooling and heating load estimate.

HEAT PUMPS: General principles, appropriate conditions for using heat pumps, theoretical and practical COP, refrigerants, absorption heat pump, applications of heat pumps; gas driven heat pumps.

TEXT BOOKS:

1. Dossat, Roy J. and Horan, Thomas J., Principles of Refrigeration, 5th Edition, Prentice Hall, 2001.
2. Arora, R.C., Refrigeration & Air Conditioning, PHI, 2010.

REFERENCES:

1. Gosney W.B., Principles of Refrigeration, Cambridge University Press, 1982.
2. Threlkeld, J.L., Thermal Environmental Engineering, Prentice Hall, 1962.

II Semester	FUNDAMENTALS OF MICROFLUIDICS (Programme Elective III)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand the fundamental theory of microfluidic systems.
CO2	Develop solutions to traditional and modern microfluidics problems.
CO3	Design, analyze, and evaluate microfluidic systems.
CO4	Understand the different fabrication essentials of micro fluidic systems.
CO5	Provide physical insights on the working of microfluidic devices and suggest system design improvements.

UNIT-I:

Introduction - Origin, Definition, Benefits, Challenges, Commercial activities, Physics of miniaturization, Scaling laws. Micro-scale fluid mechanics-Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects.

UNIT-II:

Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels. Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel.

Capillary flows- Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect.

UNIT-III:

Active microfluidics- Electro-hydrodynamics. Electro-osmosis, Debye layer, Ideal electro-osmotic flow, Ideal electro-osmotic with back pressure, Cascade electro-osmotic micro pump. Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size.

UNIT-IV:

Microfabrication essentials - Materials, Clean room, Silicon crystallography, Miller indices. Oxidation, photolithography- mask, spin coating, exposure and development, Etching, Bulk and Surface micromachining, Wafer bonding. Polymer microfabrication, PMMA/COC/PDMS substrates, micro-molding, hot embossing, fluidic interconnections. Experimental flow characterization.

UNIT-V:

Microfluidics devices - Micropumps, Microvalves, Micro flow sensors, Micro mixers, Droplet generators, Microparticle separator, Microreactors. Current trends and applications of microfluidics.

TEXT-BOOKS:

1. Nam-Trung Nguyen and Steve Wereley, Fundamentals and Applications of Microfluidics, 2nd Edition, Artech House Inc., 2019.
2. Patrick Tabeling, Introduction to Microfluidics, 2nd Edition, Oxford University Press Inc., 2019.

REFERENCES:

1. Marc J. Madou, Fundamentals of Microfabrication, 2nd Edition, CRC Press, 2011.
2. Brian J. Kirby, Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010.
3. Henrik Bruus, Theoretical Microfluidics, 2nd Edition, Oxford University Press Inc., 2008.

II Semester	INDUSTRIAL FOOD PRESERVATION (Programme Elective III)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand microbial, enzymatic, and chemical causes of food spoilage
CO2	Learn food preservation techniques like drying, freezing, irradiation, and chemical methods
CO3	Grasp the role of preservatives and additives
CO4	Monitor hygiene, sanitation, and regulatory compliance
CO5	Gain exposure to real-world food processing environments

UNIT-I

Basic food microbiology, actions of microorganisms, microbiology of food spoilage, needs and benefits of industrial food preservation; applications of thermodynamics, reaction kinetics, heat and mass transfer and water activity in food preservation; principles of fresh food storage: nature of harvested crop, plant and animal product storage, effect of cold storage and quality, storage of grains, storage at chilling temperatures, applications and procedures; freezing: physicochemical principles of the freezing process, freezing technology, calculation of heat to be removed and freezing time.

UNIT-II

Preservation processes-I: Thermal processing, interaction of thermal energy and food components, optimization of thermal processes for nutrient retention; concentration: principles of evaporator operation, membrane processes for food concentration; principles of dehydration process, energy and material balance on an air dryer, methods of drying, freeze drying; combining heat treatment, control of water activity and pressure to preserve foods; high hydrostatic pressure technology in food preservation;

UNIT-III

Preservation processes-II: Food preservation by fermentation; fermented and pickled products; beverage processes; processing of meat, fish and poultry; principles of fish salting, meat curing and smoking, purpose of smoking; food preservation by chemicals-food additives, functional chemical additives applications; chemical preservatives and antibiotics.

UNIT-IV

Food preservation by irradiation: technology aspects of radiations; pasteurization of foods, processing and storage of milk and dairy products; food packaging-principles of protective packaging; deteriorative changes in food stuff and packaging methods for prevention;

UNIT-V

Food containers-rigid containers and flexible packaging materials, and their properties; special problems in packaging perishables and processed food; evaluation of packaging, material and package performance, packaging equipment, package standards and regulation, shrink packaging, biodegradable packaging, active packaging.

TEXT BOOKS:

1. M. Karel and D. B. Lund, Physical Principles of Food Preservation, 2nd ed.
2. Marcel Dekker, 2003. P. Zeuthen and L. B. Sorensen, Food Preservation Techniques, Woodhead Publishing Ltd., 2003.

REFERENCES:

1. M. S. Rahman, Handbook of Food Preservation, 2nd ed. CRC Press, 2007.
2. G. Tewari and V. K. Juneja, Advances in Thermal and Non-thermal Food Preservation, Blackwell Publishing, 2007.
3. D. R. Heldman, Food Preservation Process Design, Academic Press, 2011.

II Semester	INDUSTRIAL HYDRAULICS AND PNEUMATICS (Programme Elective III)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Illustrate the basic concepts of fluid power
CO2	Understand the functions of elements of Hydraulic and Pneumatic systems
CO3	Analyze the functions of hydraulic and Pneumatic circuits
CO4	Illustrate the working of various hydraulic and pneumatic devices.
CO5	Interpret the procedure of installation, maintenance

UNIT-1:

FLUID POWER: Power transmission modes, hydraulic systems, pneumatic systems, laws governing fluid flow: Pascal's law, continuity equation, Bernoulli's theorem, Boyle's, Charles', Gay-Lussec' laws, flow through pipes - types, pressure drop in pipes, Working fluids used in hydraulic and pneumatic systems- types, ISO/BIS standards and designations, properties.

UNIT-II:

HYDRAULIC AND PNEUMATIC ELEMENTS: Hydraulic pipes-Types, standards, designation methods and specifications, pressure ratings, applications and selection criteria, pumping theory, Hydraulic Pumps - types, construction, working principle, applications, selection criteria and comparison, hydraulic Actuators, Control valves, Accessories - their types, construction and working, pneumatic Pipes - materials, designations, standards, properties and piping layout, air compressors, Air receivers, air dryers, Air Filters, Regulators, Lubricators (FRL unit): their types, construction, working, specifications and selection criteria of following air preparation and conditioning elements, pneumatic Actuators and Control valves - types, construction, working, materials and specifications.

UNIT-III:

HYDRAULIC AND PNEUMATIC CIRCUITS:

ISO symbols used in hydraulic and pneumatic circuit, basic Hydraulic Circuits – types (such as intensifier, regenerative, synchronizing, sequencing, speed control, safety), circuit diagram, components, working and applications, basic Pneumatic Circuits – types (such as speed control, two step feed control, automatic cylinder reciprocation, time delay, quick exhaust), circuit diagram, components, working and applications, pneumatic Logic circuit design - classic method, cascade method, step counter method, karnaughveitch maps and combinational circuit design.

UNIT-IV:

HYDRAULIC AND PNEUMATIC DEVICES:

Hydraulic and Pneumatic devices – Concept and applications, construction, working principle, major elements, performance variables of: Automotive hydraulic brake, Industrial Fork lift, Hydraulic jack, Hydraulic press, Automotive power steering, Automotive pneumatic brake, Automotive air suspension, Pneumatic drill, Pneumatic gun.

UNIT-V:

INSTALLATION, MAINTENANCE AND TROUBLE-SHOOTING:

Installation of hydraulic and pneumatic system causes and remedies for common troubles arising in hydraulic elements, maintenance of hydraulic systems, causes and remedies for troubles arising in pneumatic elements, maintenance of pneumatic systems.

TEXT BOOKS:

1. S.R. Majumdar, Oil Hydraulic Systems: Principles and Maintenance, 3rd Edition, Tata McGraw-Hill Publication, 2013.

2. S.R. Majumdar, Pneumatic Systems: Principles and Maintenance, 3rd Edition, Tata McGraw-Hill Publication, 2013.

REFERENCES:

1. R. Srinivasan, Hydraulic and Pneumatic Controls, 2nd Edition, Vijay Nicole Imprints Private Limited, 2008.

2. T. Jagadeesha, Fluid Power Generation, Transmission and Control, 1st Edition, Universities Press (India) Private Limited, 2014.

3. T. Jagadeesha, Pneumatics Concepts, Design And Applications, 1st Edition, Universities Press (India) Private Limited, 2014.

4. Andrew Parr, Hydraulic And Pneumatics: A Technician's and Engineer's Guide, 2nd Edition, Jaico Publishing House, 2013.

5. K. ShanmugaSundaram, Hydraulic And Pneumatics Controls - Understanding Made Easy, 1st Edition, S. Chand Company Ltd., 2006.

II Semester	THERMAL MANAGEMENT IN EV BATTERY AND FUEL CELL SYSTEM (Programme Elective IV)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand the fundamentals of electric vehicles, battery management systems, and fuel cells.
CO2	Apply heat transfer principles to analyze and manage battery systems.
CO3	Understand the critical role of heat transfer in the successful functioning of fuel cells.
CO4	Understand different measurements for Battery Applications.
CO5	Design and implement effective thermal management strategies for modern applications involving batteries and fuel cells.

UNIT-I:

Introduction to battery management systems and devices, fuel Cells & Batteries, Nominal voltage and capacity, Energy and power.

BATTERY CELLS: Electrochemical and lithium-ion cells, Rechargeable cell, Charging and Discharging Process, Overcharge and Undercharge, Lithium-ion aging: Negative electrode, Lithium-ion aging: Positive electrode, Cell Balancing, Temperature Sensing, Current Sensing, BMS Functionality, High-voltage contactor control, Isolation sensing, Thermal control, Protection, Communication Interface, Range estimation, State-of charge estimation.

UNIT-II:

Introduction – working and types of fuel cell – low, medium and high temperature fuel cell, liquid and methanol types, proton exchange membrane fuel cell solid oxide, hydrogen fuel cells – thermodynamics and electrochemical kinetics of fuel cells.

Basic Convective heat transfer and fluid flow, The fundamental of BTMS: Liquid cooling and Air cooling, Thermoelectric cooling, Heat Transfer Fluids in phase change materials, Heat Pipe (HP), Vapor compression, Direct refrigerant cooling Electric Motor Cooling.

UNIT-III:

Heat dissipations dependence on cold plate's channel's pattern, Heat dissipations dependence on the cold plate's number of channels and their shape, Heat dissipations dependence on the placement of the cooling plate.

High temperature batteries for back-up applications, Flow batteries for load levelling and large-scale grid application, Ni-Hydrogen batteries for space and marine applications.

UNIT-IV:

PHEV and BEV Battery Systems, Thermal Conductivity Measurements for EV Battery Applications, Battery State Estimation. EV Battery Cooling- challenges and solutions. Heat Exchanger Design and Optimization Model for EV Batteries using PCMs-system set up, selection of PCMs. Chevrolet Volt Model Battery, Thermal Management System - Case study. Modeling Liquid Cooling of a Li-Ion Battery Pack with software- simulation concepts.

UNIT-V:

Fuel cell system-balance of plant-components required. Fuel cell power plant sizing problems-Fuel Cell Electric Vehicle, Fuel economy calculations-Battery EVs Vs Fuel Cell EVs, High pressure hydrogen tank, Boost convertor, NiMH Battery, Internal circulation system, Case studies-Battery and fuel cells, Challenges and Risks.

TEXT BOOKS:

1. Dinçer, I., Hamut, H. S. and Javani, N., Thermal Management of Electric Vehicle Battery Systems, Wiley Network, 2017.

2. Hart A.B. and Womack G.J., "Fuel Cells – Theory and Applications", Chapman and Hall, 1967.

REFERENCES:

1. Andrea, D., Battery Management Systems for Large Lithium-Ion Battery Packs, Artech, 2010.
2. Söffker D., and Moulik, B., Battery Management System for Future Electric, Mdpi AG, 2020.
3. Linden D., and Reddy, T.S., Handbook of Batteries, 3rd Edition, McGraw-Hill, 2002.
4. Kiehne, H.A., Battery Technology Handbook, Marcel Dekker, NYC, 2003.
5. Nazri G.A., and Pistoa G., Lithium Batteries, Science and Technology, Kluwer Academic Publisher, 2003.
6. Husain, I., Electric and Hybrid Vehicles, Design: Fundamentals, 3rd Edition, CRC press, 2021.
7. Jiang, J., and Zhang, C., Fundamentals and Applications of Lithium-Ion Batteries in Electric Drive Vehicles, John Wiley & Sons, 2015.
8. Revankar, S.T., and Majumdar, P., Fuel Cells: Principles, Design, and Analysis, CRC press, 2014.
9. Sammes, N. ed., Fuel Cell Technology: Reaching Towards Commercialization, Springer Science & Business Media, 2006.

II Semester	MICRO AND NANO SCALE HEAT TRANSFER (Programme Elective IV)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand physics involved in fluid flow in micro scale fabricated systems and its applications.
CO2	Understand the conduction in integrated circuits and their constituent films.
CO3	Analyze the convective heat transfer in micro tubes and channels.
CO4	Analyze the heat transport at the nanoscale.
CO5	Understand the different analytical methods in nano scale heat transfer.

UNIT-I:

Introduction to microscale heat transfer - Observations on deviations from conventional theory – experimental and theoretical findings – Overview of studies and comparison of results – Introductory ideas about single phase, multiphase and gas flow in small channels – Contradictory observations and viewpoints in microchannel heat transfer- Applications of microscale heat transfer – basic ideas on micro heat exchangers and microscale heat sinks – applications in electronics cooling, biotechnology and MEMS.

UNIT-II:

Conduction in integrated circuits and their constituent films – current trends and future challenges – Microscale thermometry techniques – electrical and optical methods – thermo-reflectance thermometry – Thermal properties of amorphous dielectric films – Thermal characterization and heat transport in dielectric films – Heat conduction in crystalline silicon films – Phonon dispersion - heat conduction in semi-conductors at high temperatures – phonon transport equations – hot phonon effects.

UNIT-III:

Fundamentals of convective heat transfer in microtubes and channels – Thermodynamic concepts, general laws and particular laws - Governing equations and size effects. Single phase forced convection in microchannels – Flow structure – entrance length – experimental observations on flow and heat transfer characteristics – Theoretical investigations – Forced convection in mixtures - Gas flow in microchannels.

Boiling and two- phase flow heat transfer in small channels – Boiling curve and critical heat flux - flow patterns – Bubble dynamics and thermodynamic aspects – Mathematical modeling and measurement of microscale convective boiling; Applications of microchannel heat transfer –

microchannel heat sinks – micro heat pipes and micro heat spreaders – integration of microchannel heat sinks and heat spreaders to silicon structures – experimental and theoretical investigations.

UNIT-IV:

Fundamentals of heat transport at the nanoscale – characteristic lengths and heat transfer regimes – Nanoscale heat transfer phenomena – Conduction, radiation and convection in the nanoscale – Applications of nanoscale heat transfer in microelectronics, energy, nanomaterial synthesis, nano fabrication and biotechnology – Experimental methods in nanoscale heat transfer – thermophysical property measurement – heating and sensing based on microheaters and microsensors – Photothermal methods – Mixed optical and electrical heating methods.

UNIT-V:

Nanowires and carbon nanotubes – Thermal imaging – Analytical methods – Boltzmann equation approach and Monte Carlo Simulation for Boltzmann transport equation – The wave mechanisms - quantized incoherent transport, molecular dynamics simulation and the fluctuation-dissipation theorem approach – Multicarrier and Multidimensional Transport – coupled electron-phonon transport, multi length-scale and multidimensional transport – Challenges and Future applications.

TEXT BOOKS:

1. Ju, Y.S., and Goodson, K. , Microscale Heat Conduction in Integrated Circuits and their Constituent Films, Kluwer Academic Publishers, Boston, 1999.
2. Satish, K., Srinivas, G., Dongqing, L., Stephane, C., and Michael R. K., Heat Transfer and Fluid Flow in Minichannels and Microchannels, First Edition, Elsevier, 2005.

REFERENCES:

1. Garimella, S. V. and C. B. Sobhan, C. B., Transport in Microchannels – A Critical Review, in Annual Review of Heat Transfer, Begell House, NY, 2004.
2. Chen, G., Nanoscale Energy Transport and Conversion, Oxford University Press, 2005.
3. Mohamed Gad – el – Hak (ed.), The MEMS Handbook, Second Edition, CRC Press, 2005.

II Semester	DESIGN OF HEAT TRANSFER EQUIPMENT (Programme Elective IV)	L	T	P	C
		3	0	0	3

Course Outcomes: At the end of the course, student will be able to

CO1	Understand different types of Heat Exchangers, and their applications in the process industry and be able to analyze their thermal performance.
CO2	Design various single-phase heat exchangers.
CO3	Design various Plate Type Heat Exchangers.
CO4	Apply the principles of boiling and condensation in the design of boilers and condensers.
CO5	Understand the principles and workings of various types of heat pipes.

UNIT-I:

Classification of heat exchangers and applications, Concept of overall heat transfer coefficient, fouling factor, LMTD, effectiveness, film coefficients for tubes and annuli, equivalent diameter of annuli, caloric temperature, true temperature difference. Regenerators and recuperators. Various methods in use: ε-NTU, P-NTU, MTD methods, ψ-P and P1-P2 methods, Δ-Π Method.

Thermal design of regenerators, compact heat exchangers. Design calculation of double pipe heat exchanger, double pipe exchangers in series-parallel arrangement.

UNIT-II:

Shell and Tube Heat Exchangers-Tube layouts, baffles, classification of shell and tube heat exchangers, TEMA standards. Design calculation of shell and tube heat exchangers-shell side film coefficient, shell-side equivalent diameter, True temperature difference in a 1-2 exchanger, shell and tube sides pressure drops; Performance analysis of 1-2 heat exchangers, flow arrangements for increased heat recovery.

UNIT-III:

PLATE HEAT EXCHANGERS: Mechanical features-plate pack and the frame. Plate types; Advantages and performance limits, passes and flow arrangements, Heat transfer and pressure drop calculations. Basics of compact heat exchangers: heat transfer enhancement, plate-fin heat exchangers, tube-fin heat exchangers.

UNIT-IV:

PRINCIPLES OF CONDENSERS AND BOILERS: Condensers, Types of condensers, Heat transfer fundamentals of condensers, Nusselt theory of laminar film wise condensation; Thermal design of shell and tube condensers, Condensation outside and inside of horizontal tubes, Condensation outside and inside vertical tubes, Empirical correlations;

BOILERS- fundamentals and types of boiling, Various empirical correlations pertaining to flow boiling.

UNIT-V:

HEAT PIPES: Types and applications, operating principle, Working fluids, Wick structures, Pressure balance, Effective thermal conductivity of wick structures, Heat pipe limits, Heat pipe design procedure, Nonconventional heat pipes, Micro heat pipes, cryogenic heat pipes, pulsating heat pipes.

TEXT BOOKS:

1. Kern, D.Q., and Kern, D.Q., Process Heat Transfer, McGraw-Hill, 1950.
2. Shah, R.K., and Sekulic, D.P., Fundamentals of Heat Exchanger Design, John Wiley & Sons, 2003.

REFERENCES:

1. Kakac, S., Liu, H., and Pramuanjaroenkij, A., Heat Exchangers: Selection, Rating, and Thermal Design, CRC Press, 2020.
2. Chi, S. W., Heat Pipe Theory and Practice- A Source Book, McGraw-Hill, 1976.
3. Fraas, A. P., Heat Exchanger Design, John Wiley & Sons, 1989.
4. Dunn, P.D., and Reay, D.A., Heat Pipes, Pergamon, 1994.

II Semester	INTRODUCTION TO QUANTUM TECHNOLOGIES (Programme Elective IV)	L	T	P	C
		3	0	0	3

Prerequisites: Basic Physics, Linear Algebra, and Introduction to Modern Physics

Course Outcomes: After completing this course, students will be able to

CO1	Explain core principles of quantum mechanics and their technological implications.
CO2	Analyze quantum phenomena like superposition and entanglement.
CO3	Apply mathematical tools to model and solve quantum systems.
CO4	Demonstrate understanding of quantum algorithms and quantum circuits.
CO5	Evaluate potential applications and challenges in quantum communication and sensing.

UNIT 1:

Fundamentals of Quantum Mechanics: Historical background: Blackbody radiation, photoelectric effect, and Compton scattering; Dual nature of light and matter; De Broglie hypothesis; Schrödinger equation; Free particle, infinite potential well, step potential; Operators and observables: position, momentum, Hamiltonian; Commutation relations and uncertainty principle; Quantum postulates and measurement theory; Eigenvalues, eigenfunctions.

UNIT 2:

Quantum Information Theory: Classical vs. quantum information; Qubit representation using Bloch sphere; Quantum superposition and quantum entanglement; Dirac notation (bra-ket), tensor products, and composite systems; Bell states and EPR paradox; Quantum gates: Pauli-X, Y, Z; Hadamard; Phase; T; CNOT; Quantum circuit models and notation; Measurement in computational basis; Quantum teleportation and no-cloning theorem; Quantum state tomography (introductory)

UNIT 3:

Quantum Computing: Classical computing review and limitations; Quantum parallelism and interference; Deutsch and Deutsch-Jozsa algorithms; Grover's search algorithm, Oracle and amplitude amplification; Shor's factoring algorithm (overview and significance); Quantum Fourier Transform (QFT); Quantum error correction: Bit-flip, phase-flip, and Shor's 9-qubit code; Introduction to quantum programming: Qiskit, Cirq, IBM Quantum Experience (overview)

UNIT 4:

Quantum Communication: Introduction to quantum cryptography; Quantum key distribution (QKD): BB84 protocol; Entanglement-based QKD: Ekert protocol (E91); Eavesdropping and security of QKD; Quantum teleportation (circuit and protocol); Quantum dense coding; Quantum networks and entanglement swapping; Role of quantum repeaters; Single-photon sources and detectors; Implementation challenges (loss, decoherence, noise)

UNIT 5:
Quantum Technologies and Applications: Quantum sensors: magnetometry, gravimetry; Quantum metrology: standard time, atomic clocks; Quantum imaging and lithography; Quantum materials: topological insulators, graphene, quantum dots; NV centers in diamonds for sensing; Hardware platforms: Superconducting qubits, Trapped ions, Photonic quantum processors; Quantum supremacy and NISQ era; Global initiatives: IBM, Google, D-Wave, IonQ, India's NQM; Ethical concerns and future prospects

TEXT BOOKS:

1. **"Quantum Computation and Quantum Information"** by Michael A. Nielsen and Isaac L. Chuang
2. **"Quantum Mechanics: Concepts and Applications"** by Nouredine Zettili

COURSE OBJECTIVES:

1. To introduce fundamental concepts of quantum mechanics and its mathematical formalism.
2. To explore quantum computing and communication principles and technologies.
3. To understand the physical implementation and limitations of quantum systems.
4. To enable students to relate quantum theory to practical applications in computing, cryptography, and sensing.
5. To familiarize students with the emerging trends in quantum technologies.

II Semester	COMPUTATIONAL FLUID DYNAMICS LABORATORY	L	T	P	C
		0	0	4	2

Course Outcomes: At the end of the course, student will be able to

CO1	Develop codes for solution of algebraic and differential equations
CO2	Develop skills in the actual implementation of CFD methods with their own codes
CO3	Analyze real-life engineering applications with the help of CFD.
CO4	Design thermal engineering equipment using CFD

Using any Programming Language, code the following methods with an example:

1. Solution of 1-D parabolic equations using Explicit (FTCS, DuFort-Frankel) scheme.
2. Solution of 1-D parabolic equations using Implicit (Laasonen) scheme.
3. Fin problem with insulated and Convective end.
4. Couette Problem with and without pressure Gradient.
5. Solution of Elliptic Equations With Point Gauss-Seidel method
6. Solution of Elliptic Equations With Point Successive Over Relaxation Method
7. Solution of Linear Hyperbolic Equations using upwind and Lax explicit methods.
8. Solution of Linear Hyperbolic Equations using BTCS and Crank-Nicolson implicit methods.
9. Solution of Nonlinear Hyperbolic Equations using Lax Method.
10. Solution of Nonlinear Hyperbolic Equations using MacCormack Method
11. Primitive Variable Formulation
    - ■ Examples:
    - ● Lid Driven Cavity Problem
    - ● Mass entering and leaving a square chamber

II Semester	THERMAL SIMULATION LABORATORY	L	T	P	C
		0	0	4	2

Course Outcomes: At the end of the course, student will be able to

CO1	Formulate problems in fluid flow and heat transfer
CO2	Analyse the influence of non-dimensional parameters for heat transfer problems
CO3	Solve real life thermal engineering problems using CFD package
CO4	Design thermal engineering equipment using CFD package

LIST OF EXPERIMENTS: To perform the Simulation of the following using a CFD Package

1. Couette flow and draw the velocity profiles
2. Hagen-Poiseuille flow and draw the velocity profiles
3. Unsteady simulation of compressible flow of air through 2D a convergent – Divergent nozzle
4. **HEAT CONDUCTION THROUGH A SLAB:** To analyze the temperature distribution and hot spot temperature for a slab with different boundary conditions.
5. **LUMPED HEAT CAPACITY MODEL:** To revisit the concept of lumped heat capacity analysis via numerical analysis and predict the temperature with time.
6. **LAMINAR PIPE FLOW:** To list out the assumptions, governing equations and non-dimensional parameters for laminar flow through the pipe. Develop the numerical solution using the CFD package and compare the results with analytical solutions.
7. **LID DRIVEN CAVITY:** To list out the assumptions, governing equations and non-dimensional parameters for lid driven flow in a cavity. Develop the numerical solution using the CFD package and compare the results with published research articles.
8. **NATURAL CONVECTION IN A CAVITY (STEADY STATE):** To list out the assumptions, governing equations and non-dimensional parameters for differentially heated cavity and analyze buoyancy-induced flow. Develop the numerical solution using the CFD package and compare the results with published research articles.
9. **NATURAL CONVECTION IN A CAVITY (UNSTEADY):** To list out the assumptions, governing equations and non-dimensional parameters for differentially heated cavity and analyze buoyancy induced flow with time. Develop the numerical solution using the CFD package and compare the results with published research articles.
10. **TURBULENT PIPE FLOW:** To understand the basics of turbulence and turbulence flow models. To list out the assumptions and governing equations for turbulent flow

through the pipe. Develop the numerical solution using the CFD package and compare the results with the literature.

11. **FLOW OVER CYLINDER:** To understand the basics of external flows and flow separation. To list out the assumptions, governing equations and non-dimensional parameters for laminar flow over the cylinder. Develop the numerical solution using the CFD package and analyze the phenomena of vortex shedding by comparing the results with published research articles.
12. **HEAT TRANSFER IN POROUS MEDIA:** To understand the basics and formulations of porous media. To list out the assumptions, governing equations and non-dimensional parameters for buoyancy induced flow in a differentially heated porous cavity. Develop the numerical solution using the CFD package and compare the results with the literature.
13. **CONJUGATE HEAT TRANSFER PROBLEM:** To analyze the thermal transport for the combined solid and fluid domains.

II Semester	SEMINAR - II	L	T	P	C
		0	0	2	1

III Semester	RESEARCH METHODOLOGY AND IPR	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

- To understand the knowledge on basics of research and its types.
- To impart the concept of Literature Review, Technical Reading, Attributions and Citations.
- To know the Ethics in Engineering Research.
- To know the concepts of Intellectual Property Rights in Engineering.

COURSE OUTCOMES:
Upon successful completion of this course, the student will be able to:

	Course Outcome	***BTL (K#)***
CO1	Explain the meaning of engineering research and apply to develop an appropriate framework for research studies.	K2& K3
CO2	Identify the procedure of Literature Review, Technical Reading, etc. and apply to develop a research design during their project work.	K2 & K3
CO3	Explain and apply the fundamentals of patent laws and drafting procedure in their research works.	K2& K3
CO4	Demonstrate the copyright laws, subject matters of copyrights, designs etc. to apply in patent filing.	K2 & K3
CO5	Identify the new developments in IPR and employ the applications of computer software in writing/filing patents in future.	K2 & K3

 # Based on suggested Revised Blooms Taxonomy Level (BTL)

K1: ***Remember***	**K2:** ***Understand***	**K3:** ***Apply***
K4: ***Analyse***	**K5:** ***Evaluate***	**K6:** ***Create***

Unit Description *Contact Hrs.*

UNIT – I: **[10]**

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

UNIT – II: **[10]**

Effective literature studies approaches, analysis Plagiarism, Research ethics, Effective technical writing, how to write report, Paper Developing a Research

Proposal, Format of research proposal, a presentation and assessment by a review committee.

UNIT – III: **[10]**

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

UNIT – IV: **[10]**

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

UNIT – V: **[09]**

New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR.

TEXTBOOKS:

1. C.R. Kothari , 2nd Edition, "Research Methodology: Methods and Techniques".
2. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step-by-Step Guide for beginners"

REFERENCE BOOKS:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students.
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction".
3. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
4. Mayall, "Industrial Design", McGraw Hill, 1992.
5. Niebel, "Product Design", McGraw Hill, 1974.
6. Asimov, "Introduction to Design", Prentice Hall, 1962.
7. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
8. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

WEB REFERENCES:

- Please include hyperlinks related to NPTEL/VLabs etc.,

III Semester	SUMMER INTERNSHIP	L	T	P	C
		0	0	0	3

COURSE OBJECTIVES:

- Internships provide students with an opportunity to put into practice skills they have learned while in college.
- In addition, students should have an opportunity to enhance those skills, obtain the perspective of a work environment and benefit from a mentor or supervisor's experience and advice.

COURSE OUTCOMES:
Upon successful completion of this course, the student will be able to:

	Course Outcome	***BTL (K#)***
CO1	Integrate theory and practice to assess interests and abilities in their field of study.	K3 & K4
CO2	Develop work habits, attitudes necessary to appreciate work and its function in the economy.	K3
CO3	Develop communication, interpersonal and other critical skills to build a record of work experience.	K3

 # Based on suggested Revised Blooms Taxonomy Level (BTL)

K1: ***Remember***	**K2:** ***Understand***	**K3:** ***Apply***
K4: ***Analyse***	**K5:** ***Evaluate***	**K6:** ***Create***

III Semester	COMPREHENSIVE VIVA	L	T	P	C
		0	0	0	2

<table>
<tr><td rowspan="2">III Semester</td><td rowspan="2">DISSERTATION PART A</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>0</td><td>0</td><td>20</td><td>10</td></tr>
</table>

COURSE OBJECTIVES:

- To impart fundamental and disciplinary concepts and methods in ways appropriate to their principal areas of study.
- To familiarise how to incorporate skill and knowledge of current information and technological tools and techniques specific to the professional field of study.
- Expose to the critical aspects like identifying, analysing and solving problems creatively through sustained critical investigationusing effective oral, written and visual communications.
- To inculcate the key aspects like awareness and application of appropriate personal, societal and professional ethical standardsto excellence needed to engage in lifelong learning.

COURSE OUTCOMES:
Upon successful completion of this course, the student will be able to:

	Course Outcome	***BTL (K#)***
CO1	Carryout a critical review of literature on a chosen topic of research and identify gaps in the literature to define a problem for research work.	K3 & K4
CO2	Formulate/adapt a clear methodology using multi-disciplinary approach and modern tools.	K3& K6

 # Based on suggested Revised Blooms Taxonomy Level (BTL)

K1:	***Remember***	**K2:**	***Understand***	**K3:**	***Apply***
K4:	***Analyse***	**K5:**	***Evaluate***	**K6:**	***Create***

IV Semester	DISSERTATION PART B	L	T	P	C
		0	0	32	16

COURSE OBJECTIVES:

- To impart fundamental and disciplinary concepts and methods in ways appropriate to their principal areas of study.
- To familiarise how to incorporate skill and knowledge of current information and technological tools and techniques specific to the professional field of study.
- Expose to the critical aspects like identifying, analysing and solving problems creatively through sustained critical investigation using effective oral, written and visual communications.
- To inculcate the key aspects like awareness and application of appropriate personal, societal and professional ethical standardsto excellence needed to engage in lifelong learning.

COURSE OUTCOMES:
Upon successful completion of this course, the student will be able to:

	Course Outcome	***BTL (K#)***
CO1	Carryout design/analysis of a product/system or devise experiments to study and develop a system/process/product.	K3 & K4
CO2	Interpret & validate results of analysis/experiments conducted to study behaviour of a product /system/ process considered for the research leading to valid conclusions that add value to the body of knowledge.	K3 & K5
CO3	Write and present a technical report of the project work.	K6

 # Based on suggested Revised Blooms Taxonomy Level (BTL)

K1: ***Remember***	**K2:** ***Understand***	**K3:** ***Apply***
K4: ***Analyse***	**K5:** ***Evaluate***	**K6:** ***Create***